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(54) Ball grid package with integrated passive circuit elements.

(57) A ball grid array arrangement comprises a dielectric multilayer substrate, in a lower metallisation layer of which is disposed an array of solder balls. A passive circuit element is integrated into at least one of the metallisation layers. The arrangement may be either a discrete component consisting of a triplate transmission-line resonator or interdigitated filter integrated into an inner metallisation layer and defined by that layer in conjunction with adjacent layers, or it may take the form of an IC carrier or multichip-module carrier having such transmission structures situated within a central die-attach area of the substrate and having also a peripheral area containing bonding structures for the mounting of at least one chip or chip module. There will normally be at least two groups of such bonding structures, and a passive circuit element in the form of an inductor may be formed in the upper metallisation layer between adjacent groups of bonding structures.

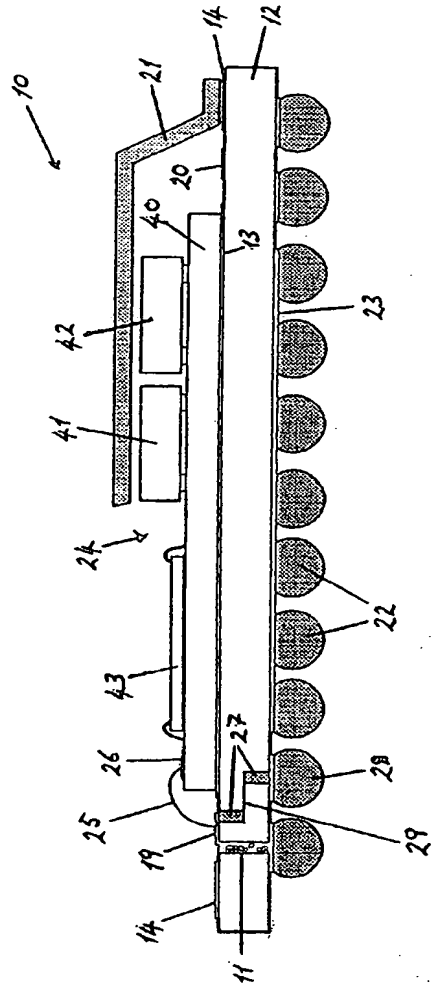

Figure 2

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ther circuitry.

The passive circuit element may be formed in the at least one inner metallisation layer within the central, die-attach area.

The peripheral area may include at least two groups of bonding structures, and the passive circuit element may be disposed in the peripheral area between adjacent groups of bonding structures. The passive circuit element may be an inductor, which may be defined in the upper metallisation layer. By integrating an inductor into the upper metallisation layer, advantage can be taken of the higher conductivity of that layer, vis-à-vis the inner layer or layers, to ensure a high Q-factor in the component, and of the increased spacing relative to the lower metallisation layer to ensure low stray capacitance and therefore high self-resonant frequency.

A capacitor may be mounted adjacent to the inductor for providing a tuning function for circuitry within the chip or chip module mounted to the ball grid array arrangement.

The ball grid array arrangement may include ground planes formed in the upper and lower metallisation layers in the central area, at least some of the solder balls in the lower metallisation layer in the central area being allocated as common ground connections for the ground planes.

The bonding structures in the peripheral area may be wire-bond pads formed in the upper metallisation layer, the pads being either signal pads or ground or power-supply pads, the pads being arranged so that at least some of the signal pads are each situated between ground or power supply pads.

A seal ring may be provided disposed around the outer part of the peripheral area, the seal ring serving as a sealing-cover bonding structure for bonding a sealing cover to the ball grid array arrangement. The seal ring may be arranged to be grounded by means of solder balls in the lower metallisation layer. Use of a sealing cover, which is preferably metal, has the advantage, firstly, of protecting the BGA package from the ingress of dirt and moisture, and secondly, where the lid is metallic, of electrically screening the device from RF interference.

The bonding structures may be disposed between the central ground plane in the upper metallisation layer and the peripheral seal ring.

Arranging for at least some of the signal-carrying wire-bond pads to be situated between pads which are at ground potential, or effectively at ground potential (i.e. power-supply pads) has the advantage of increasing the signal isolation between the signal pads.

According to a second aspect of the invention, there is provided a multichip module assembly characterised in that it includes a ball grid array arrangement, as described above, and a multichip module mounted on the ball grid array arrangement.

According to a third aspect of the invention, there is provided a multichip module radio or communications device characterised in that it includes a multichip module assembly as described above.

The invention will now be described, by way of example only, with reference to the drawings, of which:

Figure 1 is a simplified plan view of a ball grid array arrangement according to the invention;

Figure 2 is a side elevation of a multichip module assembly incorporating a ball grid array arrangement according to the invention;

Figure 3 is a cross-section of a substrate used in a ball grid array arrangement according to the invention;

Figure 4 shows parts of the arrangement of Figure 1 in greater detail;

Figure 5 shows the provision of a quarter wave triplate resonator in the inner metallisation layer of a ball grid array arrangement according to the invention;

Figure 6 shows the provision of an interdigitated triplate filter in the inner metallisation layer of a ball grid array arrangement according to the invention;

Figure 7 shows the provision of a quarter wave triplate resonator in the inner metallisation layer of a ball grid array arrangement according to the invention;

Figure 8 is a side section of a discrete ball grid array resonator according to the invention, and

Figure 9 is a side section of a discrete ball grid array filter according to the invention.

Referring to Figures 1, 2 and 3, a simplified plan view of a ball grid array arrangement 10 according to a first embodiment of the invention is shown, comprising a multilayer substrate 12, which consists of three metallisation layers 30, 31, 32 and two intervening dielectric layers 33, 34. In the upper metallisation layer 30 are formed a central die-attach pad 13 forming a ground plane, a peripheral seal ring 14 and four groups 15-18 of wire-bond pads 20. A central part of the lower metallisation layer likewise contains a ground plane. The substrate 12 is constructed using a cofired ceramic technology with refractory metallisation systems such as tungsten or molybdenum and an alumina (or aluminium nitride) dielectric material. In this process, the metallisation patterns are defined by screen-printing tungsten or molybdenum powder inks onto unfired Al_2O_3 layers in tape form. The tape comprises the powdered ceramic dielectric held together by an organic binder. When the patterns have been printed, the various layers of tape are laminated together and the resulting body fired at between 1650 and 1900°C to remove the binders and to densify the structure.

The seal ring 14 allows an electrically conductive lid 21 to be bonded to the BGA, using either a gold-tin eutectic alloy composition or lower melting-point

applies to most of the signal pads in the group, exceptions being the signal connections numbered 5-9 and 11.

It is also found that the local proximity of the grounded package base metallisation 23 (see Figure 2) and the grounded seal ring structure 14 helps to shield the emerging signal trace connections and maximises isolation.

The bulk of the central area of the BGA package is employed almost exclusively for establishing ground connections with the external circuitry with which the MCM is associated, and therefore no inner-layer traces are required inside this area. The invention takes advantage of this to incorporate into the inner metallisation layer passive components which function as resonant or filter elements, or as tuning and adjusting elements for the circuitry in the MCM. One such component, shown in Figure 5, is a quarter wavelength resonator, realised in triplate form. The resonator 60 consists of a strip 61 of inner metallisation 31 coupled by means of appropriate via routing to one or more wire-bond pads 20 at the, in this case, right-hand edge of the BGA package 10. The resonator relies for its operation on a transmission line effect that exists between the strip 61 and the parallel-lying upper and lower ground planes 13 and 23 (see Figure 2), the three metallisation structures forming then what is known as a triplate structure. The alumina ceramic composing the substrate of the present embodiment has a relative permittivity, ε_r, of approximately 9.8 at 2.4 GHz, which means that, if the resonator is to be a quarter-wave resonator at that frequency, it needs to be 10 mm in length. The line width for a 50 ohm impedance triplate structure in the 0.6 mm thick package base illustrated in Figure 2 is about 0.3 mm. The resistance of such a line in a typical inner-layer tungsten metallisation having a resistance of 10 mΩ per square, is about 0.33 ohms. This resistance governs the Q-factor of the resonator.

The area occupied by the resonator 60 is conveniently restricted to those parts of the central area of the BGA package which lie between the solder balls 22, i.e. the strip 61 runs between adjacent rows of solder balls 22, and approximately parallel to them. The 50-ohm width of the resonator, i.e. nominally 0.3-0.4 mm, fits comfortably within the inter-ball pitch, which is approximately 1.5 mm.

Another passive element that may be incorporated into the substrate in the central area is an interdigitated triplate filter. Such a filter structure, which may be employed as a transmit and/or receive chain band-pass filter, for example, is illustrated in Figure 6. In Figure 6, a filter 70 consists of three quarter-wavelength strips 71-73 of inner metallisation 31, each having a width and length similar to that of the resonator 60 in Figure 5 to achieve a 50-ohm impedance, and each co-operating with neighbouring upper and lower metallisation layers to form a triplate transmission line system as in the case of the resonator 60. Again, connections to one end of each of the strips 71-73 are made by way of vias and, where necessary, further traces linking with the wire-bond pads 20, but this time connections are taken from opposite sides of the BGA package 10. Thus, the outer strips 71, 73 are fed from, in this case, the right-hand side of the BGA package, while the centre strip 72 is fed from the left-hand side. Filter tap points may also be placed along the length of the outer filter elements according to the specific design required.

Because a cofired ceramic fabrication process is employed for the BGA package 10 in this embodiment, the dimensional instability inherent in the firing process must be taken into account the dimensions of the resonator or filter elements are calculated. This instability takes the form of shrinkage, typically 16% in linear dimensions with a tolerance of ±0.5%. These tolerances lead to similar tolerances in the electrical characteristics of the resonator or filter employed, i.e. its resonant frequency and bandpass characteristics, respectively. In order to achieve tighter tolerances, a combination of triplate and surface microstrip constructions (not shown) are employed to allow trimming and tuning of these components after manufacture. This is realised by arranging for the majority of the length of a resonator or filter element to be defined in the triplate format described above, but completing the length with the addition of a short length of microstrip formed in the upper or lower metallisation 30, 32. This measure takes part of the element onto the package surface, where laser or abrasive trimming may be employed to adjust the length and resonant behaviour of the line. Care must, however, be taken to ensure that there is minimal discontinuity in the transition between the two formats.

In a second embodiment of a BGA arrangement according to the invention, a PCB-type construction of the substrate is used, rather than a cofired ceramic construction. This employs plated copper metallisation bonded to organic composite laminate materials. Gold wire bonding alone is employed here, in contrast to the gold or aluminium bonding which may be used in the ceramic type of construction. The PCB-type system has the disadvantage that the polymeric materials employed are not as dimensionally stable as the ceramic materials. There is also the fact that alumina ceramic materials can be selected which have very low dielectric loss at the frequencies of interest, whereas dielectric losses in the polymeric materials are likely to be somewhat higher, depending on the level of additives, e.g. fire retardants, incorporated into the laminates involved.

On the positive side, however, the PCB-type construction does have the advantage that, since photolithographic methods can be employed to form the necessary metallisation patterns, these patterns and hence their dimensions can be very accurately con-

ground planes in the upper and lower metallisation layers. Other arrangements are possible involving the use of more than three metallisation layers, and where such are used, the triplate structures hereinbefore described may be formed in three adjacent inner layers instead of in the two outer layers and one inner layer. Suitable via structures will then be necessary to link parts of these additional layers with each other and with the outer layers and the solder balls, as necessary.

Claims

1. A ball grid array arrangement (10) including a dielectric multilayer substrate (12) having an upper, a lower and at least one inner layer of metallisation (30, 32, 31), the lower metallisation layer (32) including an array of solder balls (22), characterised in that a passive circuit element (60, 70, 75, 81, 100) is integrated into at least one of the metallisation layers.

2. A ball grid array arrangement as claimed in Claim 1, characterised in that the passive circuit element is a triplate line resonator transmission-line structure 60 formed in the at least one inner metallisation layer (31) and defined by that layer in conjunction with adjacent metallisation layers (30, 32) and intervening dielectric layers (33, 34).

3. A ball grid array arrangement as claimed in Claim 1, characterised in that the passive circuit element is an interdigitated filter transmission-line structure (70) formed in the at least one inner metallisation layer (31) and defined by that layer in conjunction with adjacent metallisation layers (30, 32) and intervening dielectric layers (33, 34).

4. A ball grid array arrangement as claimed in Claim 2 or Claim 3, characterised in that the transmission-line structure is terminated by a surface microstrip section formed in the upper or lower metallisation layer, the microstrip section serving to provide an exposed region of metallisation that can be selectively removed to trim the electrical response of the transmission-line structure.

5. A ball grid array arrangement as claimed in Claim 4, characterised in that a dielectric coating is provided over the surface microstrip section to improve its optical absorption for laser trimming.

6. A ball grid array arrangement as claimed in Claim 4 or Claim 5, characterised in that the transmission-line structure is formed between adjacent rows of solder balls (22).

7. A ball grid array arrangement as claimed in any one of the preceding claims, characterised in that it includes one or more ground planes (13, 23) formed in at least one of the metallisation layers.

8. A ball grid array arrangement as claimed in any one of the preceding claims, characterised in that the substrate includes a central, die-attach area (13) for the mounting of at least one chip or multichip module (24) and a peripheral area containing bonding structures (20) for establishing electrical connections between at least some of the solder balls (22) and the at least one chip or multichip module (24).

9. A ball grid array arrangement as claimed in Claim 8, characterised in that the passive circuit element is formed in the at least one inner metallisation layer (31) within the central, die-attach area (13).

10. A ball grid array arrangement as claimed in Claim 8, characterised in that the peripheral area includes at least two groups of bonding structures (15, 16, 17, 18), and the passive circuit element is disposed in the peripheral area between adjacent groups of bonding structures.

11. A ball grid array arrangement as claimed in Claim 10, characterised in that the passive circuit element is an inductor (75).

12. A ball grid array arrangement as claimed in Claim 11, characterised in that the inductor (75) is defined in the upper metallisation layer (30).

13. A ball grid array arrangement as claimed in Claim 11 or Claim 12, characterised in that it includes a capacitor (76) mounted adjacent to the inductor (75) for providing a tuning function for circuitry within the chip or chip module (24) mounted to the ball grid array arrangement.

14. A ball grid array arrangement as claimed in any one of Claims 8 to 13, characterised in that it includes ground planes (13, 23) formed in the upper and lower metallisation layers (30, 32) in the central area, at least some of the solder balls (22) in the lower metallisation layer (32) in the central area being allocated as common ground connections for the ground planes.

15. A ball grid array arrangement as claimed in any one of Claims 8 to 14, characterised in that the bonding structures in the peripheral area are wire-bond pads (20) formed in the upper metallisation layer (30), the pads (20) being either signal pads or ground or power supply pads (V1-V4), the

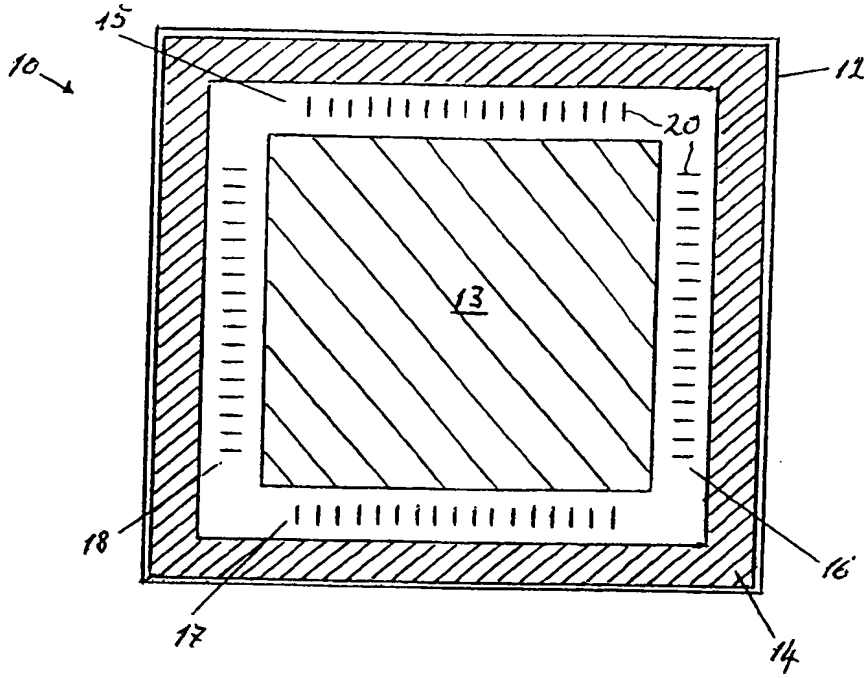

Figure 1

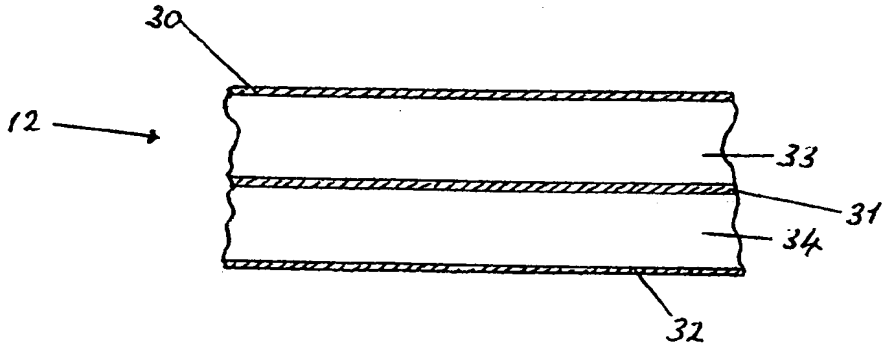

Figure 3

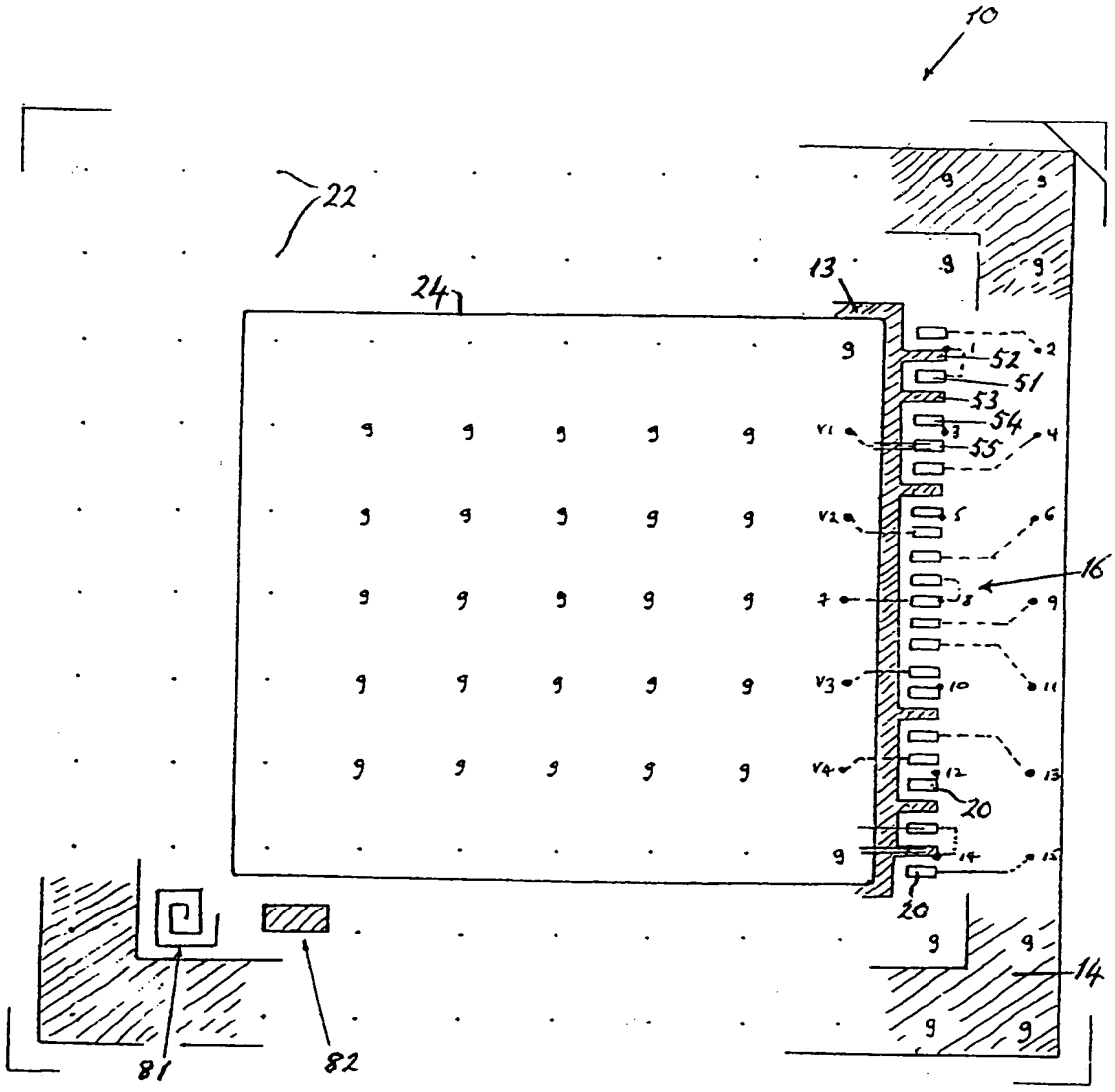

Figure 4

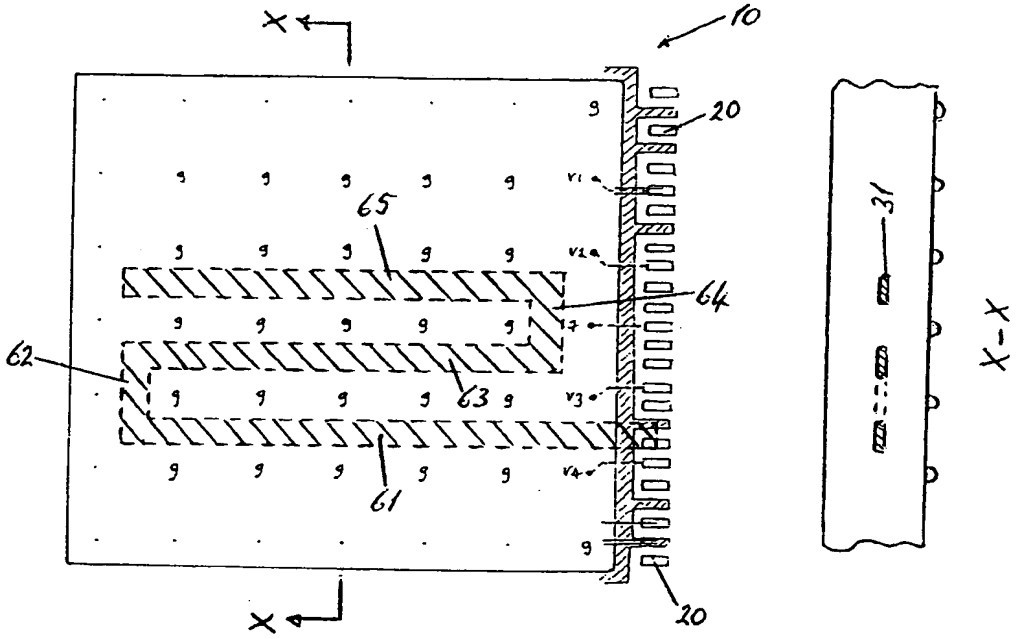

Figure 7

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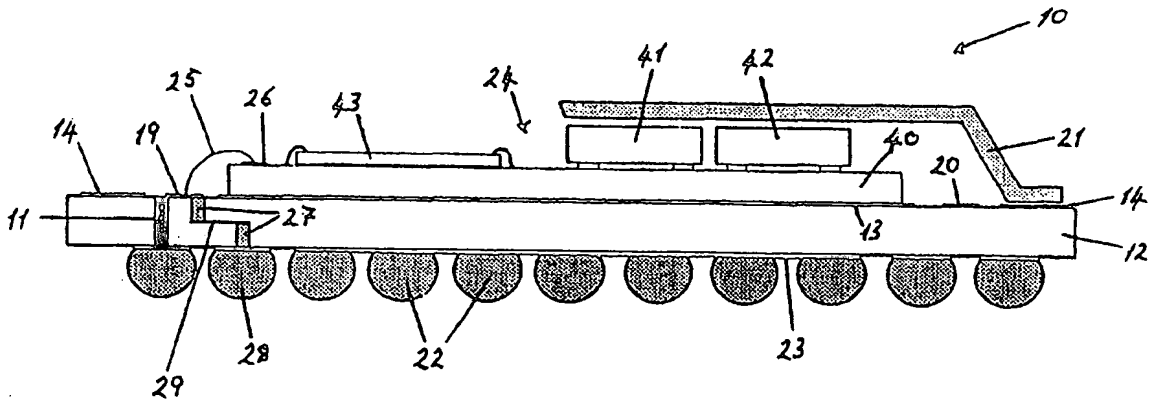

Figure 2

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